Distillation Tower Flooding — More Complex Than You Think

While other "predictive" methods tell too little, too late, gamma scans indicate where and why flooding occurs — invaluable insight for troubleshooters

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Flooding in distillation columns has been defined as "excessive accumulation of liquid inside the column," [1] "inoperability due to excessive retention of liquid inside the column," [2] and even a point where "it is difficult to obtain net downward flow of liquid, and any liquid fed to the column is carried out with the overhead gas." [3] While these descriptions appear to be similar at first glance, they actually describe different stages or degrees of flooding. Excessive accumulation of liquid may or may not cause inoperability, and inoperability may or may not carry the feed liquid out with the overhead gas.

Fortunately, the variance of these definitions rarely derails the performance of new column designs. Well-designed modern towers provide their operators with a comfortable margin of safety as regards flooding, and different incipient-flood-point (IFP) definitions give surprisingly little scatter of flood-point data [4]. However, when existing columns require troubleshooting or debottlenecking, inconsistent definitions of the flooding initiation point may lead to different — sometimes even wrong — revamp designs, due to lack of understanding about the cause and location of the flooding condition. In fact, once the monitored operating parameters (such as pressure drop) show evidence of flooding, most columns are way past their IFP and are well on their way to a fully flooded state.

To avoid these precarious situations, gamma scans have proven to be a reliable tool for determining the location and extent of flooding, because they can measure the liquid holdup in a column directly [8,9]. A gamma scan is accomplished by simultaneously lowering a gamma-ray source and a radiation detector down the sides of a column.

The gamma-ray transmission through the column is affected by column internals, the process fluids, and possibly by external influences, such as manways or stiffening rings. Any external influences are documented during the scan and are labeled as comments on the data results.

The impact of column internals, such as trays, packing, or internal pipes, upon scans can be evaluated from mechanical drawings and past experience. Then, the remaining influence on the gamma-ray transmission can be attributed to the process fluids inside the column.

In addition to solving flooding problems, insightful analysis of the dynamic flooding mechanism will benefit the development of an advanced control system and improve operating procedures for pushing a column to its maximum capacity.

The following sections present diagnostic case studies for investigating the flooding phenomena in trayed and packed columns by gamma-scan technology. For a guide to the interpretation of gamma-scan plots, see the box on p. 63; and for more on why flooding occurs, see the box "Understanding Flooding" (next page).

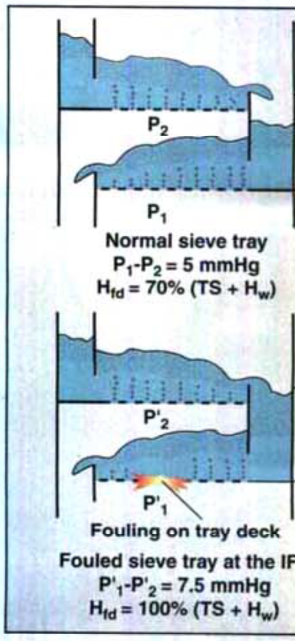


FIGURE 1. In this incipient-flood tray, fouling has caused an increase in pressure drop and downcomer liquid backup (P = pressure, mmHg; H_{fd} = downcomer backup, mm; TS = tray spacing, mm; H_w = outlet weir height, mm)

TRAYED COLUMNS

The IFP data on a column must answer two questions — when (at what throughput) and where (at what location) the column starts to flood.

Traditional measurements of pressure drops, temperature profiles, and liquid levels usually cannot tell exactly where flooding has originated in a column, particularly with a large number of trays or a large height of packing bed. In these cases, the IFP will have come and gone before the traditional measurements show any response.

Pressure-drop (ΔP) increase has been most widely recommended as an indication of flooding. Let us take a closer look at how the ΔP responds to the incipient flood in a trayed column.

A typical sieve tray has a ΔP of 5 mmHg. For a 30-tray column, with tray spacing of 24 in. (610 mm) and an outlet weir of 2 in. (50 mm), the total pressure drop from the top to the bottom of the column would be 150

UNDERSTANDING FLOODING

In addition to the three definitions mentioned in the main text, there are many other descriptions of "flooding" for different types of column internals [1,4–7]. In the 1998 Fractionation Research Institute report [2], evidence of flooding includes the following:

- High pressure drop
- Continuously increasing pressure drop (even if only slowly)
- Reduced bottoms product rate (may be sudden)
- Loss of column mass balance (total product rates seem to be less than total feed rates)
- Poorer separation performance
- A narrower temperature profile (increasing top and/or reducing bottom temperatures)

Field experience illustrates that a problem column can have a "flood escalation period" anywhere from several minutes to several hours, depending on the column size and throughput. During this period some of these indications appear early on, while others show up much later.

For instance, in a trayed column, higher degrees of entrainment carry more liquid upward from tray to tray, lowering the tray efficiency as liquid from a tray of lower volatility is physically carried to a tray of higher volatility. Entrainment will increase the liquid retention in a column. When the loss of efficiency causes off-specification distillation products, then the entrainment is said to be "excessive". At this point the liquid accumulation would also be considered "excessive", as the needed separation efficiency is lost. The column would be considered flooded as the first definition in the main text [1] stipulates.

This "excessive accumulation" of liquid and entrainment would not necessarily cause the column to be "inoperable". However, if the entrainment were to increase further, the entrained liquid would continue to accumulate even on trays where the tray spacing is larger, such as at a feed point. But for example, if an area or device for handling a two-phase or flashing feed were submerged with the accumulated liquid, then the column would have problems of operational instability, or inoperability. At this point the column would be considered "flooded" based on the second definition in the main text. However according to the third definition, the column has not "flooded" since the feed liquid is not yet being carried out with the overhead gas.

A more inclusive definition

We believe that flooding is a dynamic process of liquid accumulation that develops from the incipient flood point to a fully flooded condition. Therefore, our definition of flooding is adapted to describe the entire flooding process.

Incipient flood point (IFP) is the combination of vapor and liquid loads at which liquid downward traffic begins to choke or slow down. Incipient flood may begin on a tray, in a section of a packed bed, at a feed or draw device, or at any other internal in a column.

Most flood-point data in literature were collected from observations of IFP in laboratory test columns. Literature flood-point data typically show good consistency because most such data were measured on small and well-controlled test columns.

The flooding process starts from the IFP and ends with a fully flooded column, if the vapor/liquid loads in the column are not reduced. Once the flooding process begins, high liquid inventory inside the column will increase the pressure drop across the column, impede phase separation and lower the separation efficiency. The column may become inoperable or uncontrollable due to excessive retention of liquid inside the column. During the flooding process, one or more trays might become fully flooded, but the column could still be functional.

The fully flooded state is the end of the flooding process, where it is impossible to obtain net downward flow of liquid, and any liquid fed to the column is carried out with the overhead gas. In this state, a significant part or the whole volume of the column, is full of liquid and vapor bubbles through the liquid. The column completely loses its operability or function when fully flooded. ❐

mmHg. Assume that one of the trays floods because of fouled sieve holes. Liquid backup in the downcomer will increase, because of the increased pressure drop across the tray, from its normal height of 18 in. (460 mm), based on 70% tray spacing plus weir height, to its IFP height of 26 in. (660 mm) (Figure 1).

The ΔP of the incipient flood tray will increase by the liquid head equivalent of 26-18 = 8 in. (200 mm) of froth height. For simplicity, assume the froth contains 50% vapor and the liquid specific gravity is 1.0; therefore the column's pressure drop increase will be 4 inH_2O (7.5 mmHg).

In other words, at the IFP, the pressure drop of the column would change only about 5%. Depending on the location of the pressure drop measurement points, the pressure drop data may — but most probably will not — be able to tell you which tray has caused the flooding.

Fully flooded column

A deethanizer column with 26 trays had experienced severe surge problems and poor separation. The column was scanned from its top to its bottom. The tray vapor spaces in the column were extraordinarily dense as the raw gamma-ray "counts" (solid blue line in Figure 2) transmitted through the tray vapor spaces were only 150-200 counts, instead of the expected range of 1,000 counts. Thus, the column must be full of liquid or fully flooded.

In an operating column, unloading or reducing feedrates is the most commonly applied method to relieve the flooding problems [1]. And, for a fully flooded column, the accumulated liquid must be drawn off from the bottom until the liquid level is below the reboiler return nozzle. Unfortunately, there was not a functional bottoms liquid level gauge available on this deethanizer. In order to monitor the process of unloading the column, a gamma-ray source and detector were set up just below the reboiler return nozzle, while operations tried to unload the column. In this stationary monitoring technique, (see the box, p. 65) the gamma transmission counts will have a sudden increase when the liquid level is lowered below the monitoring spot. Once the bottoms liquid level is detected below the reboiler return nozzle, the column can be slowly returned to full rates.

As suggested in the deethanizer case, the bottoms liquid level should continue to be monitored to make sure it stays below the reboiler return nozzle. Our experience has shown that a significant number of columns flood due to lack of control of, or lack of a correct indication of, bottoms liquid levels.

Once the deethanizer column was stabilized, a second scan was performed to check the integrity and operating condition of the trays. The

second scan showed that the liquid holdups on all 26 trays were at the proper elevations and that the trays were holding aerated liquid (red line in Figure 2). The deethanizer trays appeared to be operating with slight to moderate entrainment.

Top tray flooded

As mentioned earlier, when a column becomes fully flooded, liquid will be carried out with the overhead gas. However, liquid carryover, per se, might not mean that a column is fully flooded, since the column may still be able to be take feed and produce products. Nevertheless, liquid carryover could be detrimental to the stability of the overhead product, or to the proper functioning of the condensation system and downstream processes.

In another example, operations personnel for a deisobutanizer were having trouble controlling the level of the overhead accumulator. Pressure drop of the 80-tray column did not show any recognizable problem. But the feed to the deisobutanizer had to be greatly reduced to gain control of the top accumulator level.

The deisobutanizer column was scanned to determine tray integrity and operating conditions. The scan showed that there was liquid retention from the top tray, Tray 80, up into the top head where the scan initiated (Figure 3). From this type of scanning result, there are two likely possibilities. The most likely explanation for the top tray being fully flooded is a restriction in the downcomer of the top tray. Another possibility could be that Tray 80 had accumulated the entire entrainment induced from the lower trays.

In this case, one flooded tray at the top of the column did conform to one definition of flooding (liquid carryover), but the column still should not be considered fully flooded. The large tray space above the top tray, approximately twice the tray spacing between the other trays, could tolerate higher liquid backup and still allow the reflux liquid to go downward to the next tray. Also, the loss of separation efficiency was minimal for the 80-tray column, since it actually lost the service of only one tray.

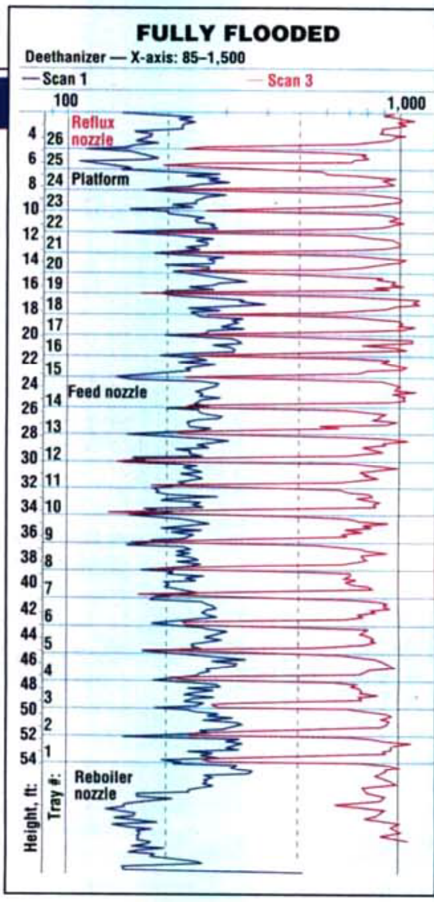


FIGURE 2. Blue curve shows abnormally dense tray-vapor spaces, indicating tray spaces that are full of liquid or a flooded column. Red curve shows a normally operating column

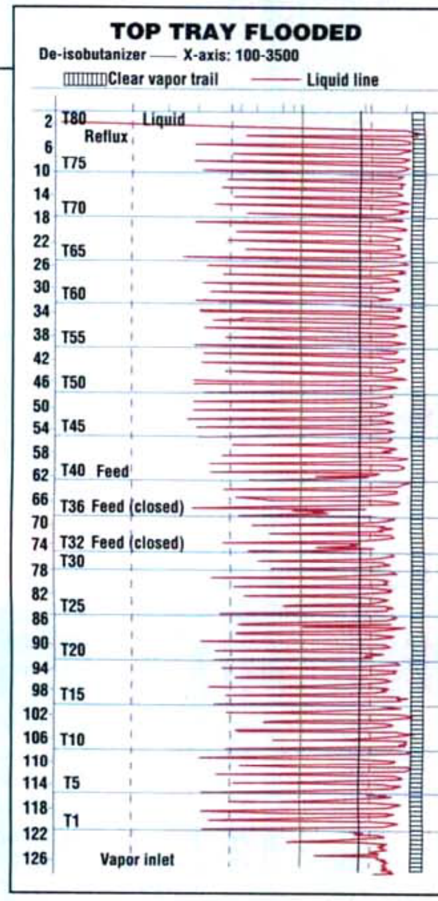


FIGURE 3. While liquid is stacked on the top tray (Tray 80), the liquid carryover does not signify a fully flooded column

Entrainment severity

"Jet flood" or "entrainment-flood" is widely used to describe the upper operating limit of a column — where the spray or froth height on trays increases beyond the tray spacing, and entrainment on a massive scale takes place. The flooding process of entrainment-flood could develop from its IFP to a fully flooded column over a wide range of vapor-liquid rates. The entrainment rate is not always constant within a column, as it changes with the tray design and tray location. For industrial columns — as opposed to those of laboratory-scale — with the possibility of compromised internals and complexity of hydraulics, neither the entrainment rate nor its flood point can always be confidently predicted.

A basic phenomenon when jet flooding occurs is that the normal vapor-liquid disengagement spaces above the tray decks are filled with droplets or frothy liquid, which is easily recognizable from a gamma-scan plot. However, it may be not easy to differentiate entrainment-flood from severe entrainment by means of the gamma-scan plot alone.

Most distillation columns can tolerate a certain amount of entrainment without an overall loss of performance. A column can even perform well with severe entrainment if the downcomer area is sufficient to handle the entrained liquid. Figure 4 shows a scan for an 80-tray column, which was not experiencing any problem. The purpose of the scan was to provide pre-turnaround information about the general integrity and operating conditions of the trays. From an interpretation of the scan results, the overall conclusion was that the column was operating with severe entrainment. The gamma-ray counts transmitted through the tray vapor spaces never reached the clear-vapor bar (green bar on the right side of Figure 4), except in the vapor spaces at the top of the column, at the manways, and below the bottom tray.

The clear-vapor bar is a reference based on the point at which the lowest vapor density was observed in the column. The clear vapor is assumed to be liquid-free and is used as a reference for normal disengagement between trays.

A closer look at the bottom trays,

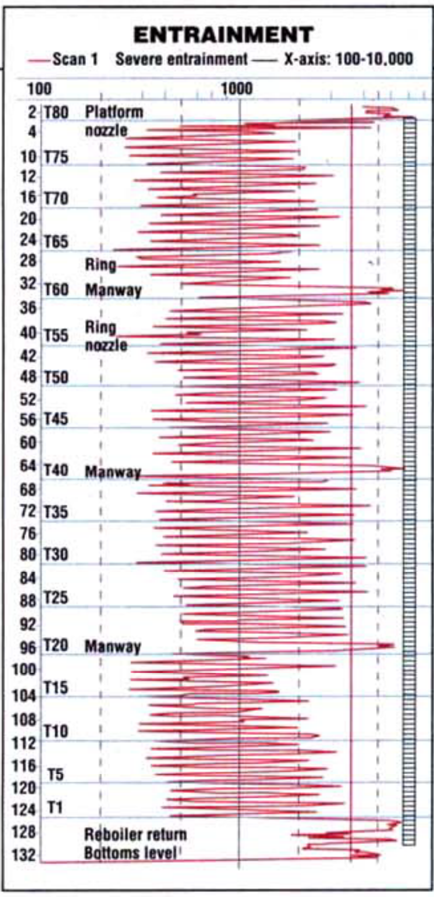
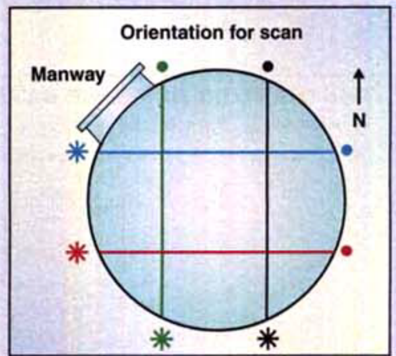


FIGURE 4. In this case, entrainment was increasing gradually from Tray 1 up to Tray 20 (with increasing density of the vapor spaces). Entrainment accumulation stopped at Tray 20, which has a larger tray spacing (manway). It was the larger spacing at this manway that saved the column from flooding completely

INTERPRETATION GUIDE FOR THE GAMMA-SCAN PLOTS

As applied to distillation columns, gamma scanning uses a small, sealed radiation source and a sensitive detector aligned on opposite sides of the column. The scanning apparatus is kept on the outside surface of the process equipment, so the procedure is completely non-invasive and non-interactive to the normal operation of the process.



Based on the fundamentals of radiation, the radiation intensity passing through a material decreases exponentially as a function of the material density. Or stated differently, an increase in material density or thickness results in a measurable reduction in radiation intensity. As noted in the main text, the gamma-ray transmission through a distillation column is affected by the column internals, the process fluids, and by external factors such as manways and stiffening rings. External factors are noted during the scan and labeled as comments on the scan data plots. The impact of column internals is evaluated based on column mechanical drawings and from past experience. The remaining influence on the gamma ray transmission is then related to the process fluids inside the column.

In the scan data plots used in this article, the column elevation is on the vertical scale, with the top of the column at the top of the figure. The horizontal scale is the gamma ray transmission or radiation intensity through the column. Low radiation intensity (low "counts") represents higher density areas, such as liquid, inside the column. Conversely, high radiation intensity (high "counts") represents lower density areas, such as vapor spaces. Thus, when examining these figures, think of process density with higher values toward the left side of the figures and lower values on the right-side.

Typically, trayed columns are scanned with the radiation beam passing across the tray active area, or through the downcomers. For a packed column, the usual scanning procedure uses four scan lines, in a 2x2 grid with equal chord lengths, as shown below. One of the more critical aspects with regard to a packed column operating satisfactorily is the liquid distribution through the packing.

The basis for the grid scan is that uniform or good liquid distribution also has uniform or equal bulk density through the four scan chords. Therefore, when the data plots of all four scan lines coincide — or overlay on top of each other — there is uniform liquid distribution through the packing. Problems are diagnosed when non-uniformity is observed from the scan data plots. Any divergence among the scan data can be an indication of maldistribution. Lower radiation intensity indicates excess liquid, and higher radiation intensity is associated with liquid deficiency. ❑

Trays 1-20, showed that the entrainment was gradually increasing from Tray 1 to Tray 20. In other words, liquid was being entrained upward tray-by-tray, and the overall liquid rate passing through a given tray downcomer (liquid from the tray above plus the entrained liquid) was higher than that for the tray below. But the entrainment propagation stopped at Tray 20, where the tray spacing increased due to a manway. Thus the column was not fully flooded, because the upper trays were still operating below the entrainment-flood point. It was the larger spaces at the manways that saved this column from reaching a fully flooded state.

Since severe entrainment reduces tray efficiency, more trays will be needed for the same separation specifications. In this particular case, the number of trays in the column compensated for the entrainment-efficiency loss.

Catching the IFP

When we wish to push an operating column to its maximum, or to de-bottleneck a column, we need to know where flooding starts, what starts it, and the liquid load or vapor load when it starts. This topic has been covered in more detail in Reference [8]. In this present article, we suggest the step-by-step approach below.

When evaluating the IFP in a large column, one needs to follow a systematic, logical approach. Our case study involves a company that was increasing the capacity of a natural-gas treatment plant. Simulations showed that the deethanizer column was going to be a capacity bottleneck. The engineers wished to know, in more detail, the conditions where and when the deethanizer became limited; that is, the IFP of the deethanizer.

The first step was to establish a baseline set of data on the column. At the existing plant capacity there were no known problems with the operation of the deethanizer. A baseline scan of the 2-pass trayed deethanizer, was made on tray active areas and center downcomers to document the deethanizer operating condition at this given set of test conditions. In this particular case, the baseline results (Figure 5) showed a hint of where the IFP might be. All of the tray active areas looked good; none had any severe entrainment. The center downcomers of all the trays, except the bottom two trays, appeared normal. However, the center downcomers of the bottom two trays, Trays 49 and 51, appeared to be full of aerated froth.

To simulate the operation at the proposed increased rates, the reflux was increased 15% with an appropriate increase in reboiler rates to maintain the deethanizer heat balance. The deethanizer was scanned again for both active areas and center downcomers. The results showed flooding at the top of

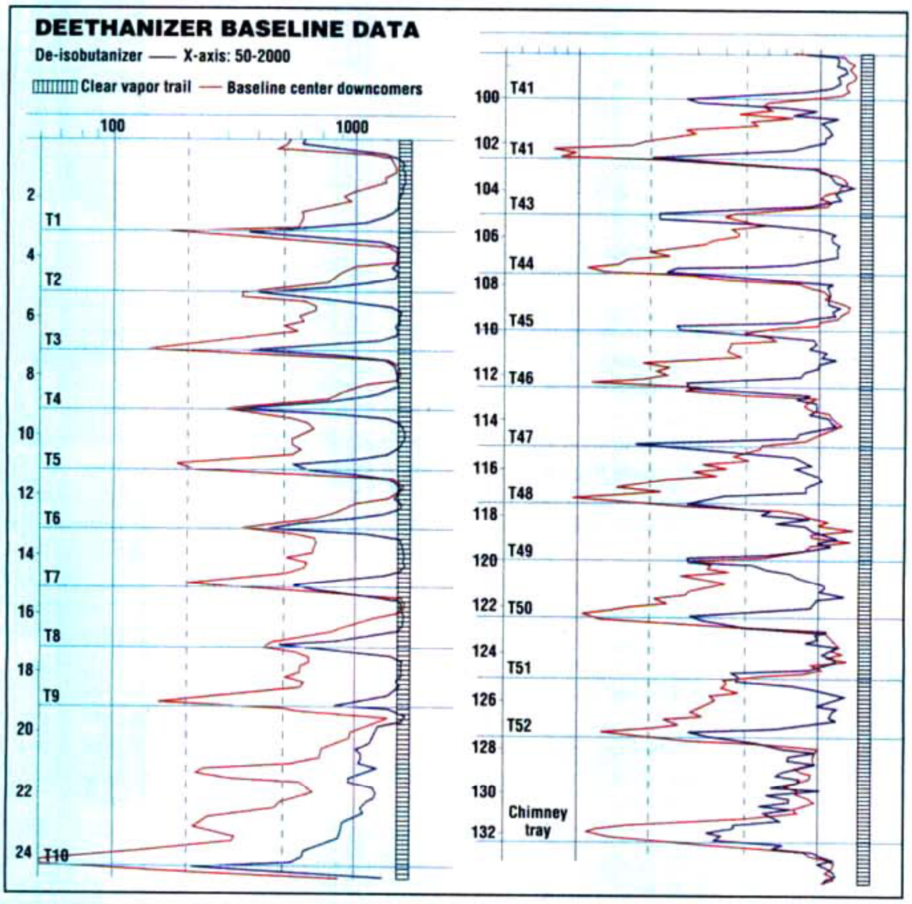


FIGURE 5. Baseline scans showed center downcomers in the bottom of the deethanizer nearly full of froth

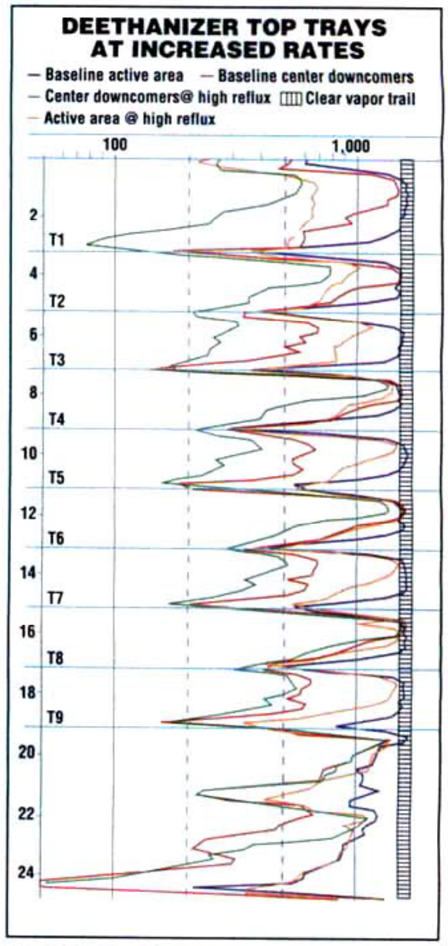


FIGURE 6. The scans of this column show the top-three trays flooding with reflux carried overhead

the deethanizer (Figure 6). The top three trays were flooded with reflux being carried overhead from the deethanizer. The flooding gradually subsided until the 8th and 9th trays matched the baseline profile.

In the bottom of the deethanizer (Figure 7), the tray active areas still appeared the same as they had on the baseline but the center downcomers had filled to capacity with froth. The scan at the higher rates showed two problem areas, but it was unclear which had happened first. It would have been a logical conclusion to believe that the bottom trays would flood first, since their downcomers had been full at the baseline conditions. But since the top trays unexpectedly flooded at the increased rates, it was possible that the top trays were the starting flood point.

To confirm exactly where the flooding started first, the operating rates were returned to the baseline conditions. Three points were selected for stationary monitoring — between the top two trays, above the bottom tray, and below the feed point. As rates were slowly and gradually increased, these points were continuously monitored to see which would flood first.

As Figure 8 shows, the top trays flooded first. This testing also confirmed to the designers that the bottom section of the deethanizer operated in the "emulsion" regime — a location where the vapor is bubbling through the continuous liquid phase when operating at higher pressures and higher liquid rates. In the emulsion regime, downcomer limitations are the primary cause of tray capacity problems [*10*]. This result was expected; but the surprise was that the deethanizer flooding actually occurred first at the top of the deethanizer. Reference [*11*] includes more on the detection of the flow regimes on trays.

PACKED COLUMNS

Packed columns, like trayed columns, have limitations in their capacity to handle vapor and liquid loads. As with trayed columns, we speak of this limitation as "flooding". But, unlike the situation with trayed columns, characterizing the flooding phenomena in packed columns seems to be much more complicated, with even more disagreement among the "definitions". Liquid accumulation is more difficult to observe in a continuous packed bed than on staged trays — even in laboratory columns.

For a given packed column, at the high end of liquid and vapor rates we encounter flooding as liquid backs up the column and fills all the void space in the packing bed. Poor disengagement between vapor and liquid (backmixing) reduces the separation efficiency, and the high liquid holdup in the bed increases the pressure drop.

The traditional approach to analyzing flooding in packed columns relies on measuring pressure drop (Figure 9). At low liquid rates, the open area of the packing is practically the same as for dry packing. In this regime the pressure drop is proportional to the

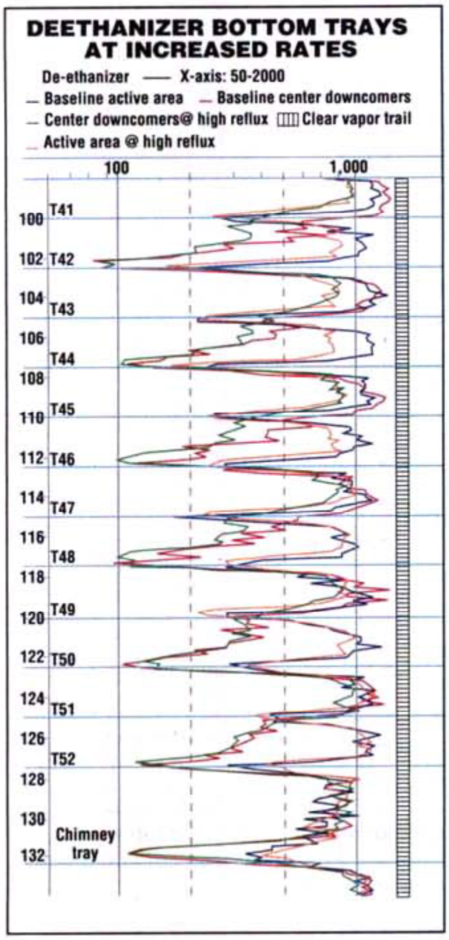


FIGURE 7. Center downcomers of trays in bottom of deethanizer were full of froth, but tray active areas looked the same as they did at the baseline conditions

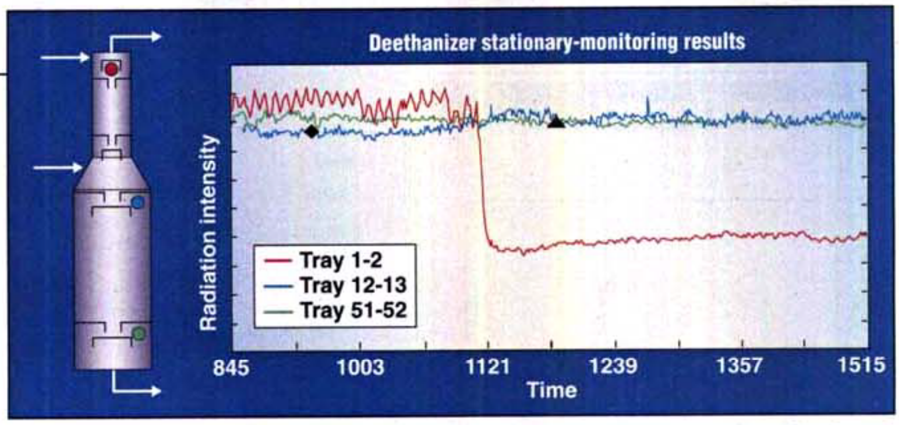
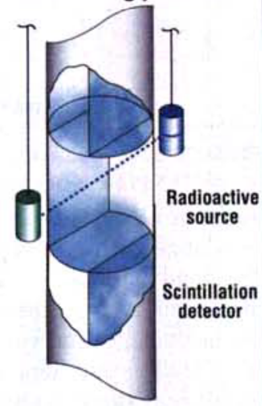


FIGURE 8. As operating rates were increased, continuous stationary monitoring of three key spots on the deethanizer showed that the top trays were the first to flood

STATIONARY MONITORING

The traditional gamma scan has the source and detector moving down the column in discrete increments. Each discrete gamma measurement is plotted to generate a density profile of the online process, as explained earlier. Stationary monitoring, however, utilizes an immobile source and detector at a particular point on the process equipment to monitor density changes versus time — instead of density versus elevation. This technique is useful in numerous applications, such as identifying the incipient flood point of trays or packing; monitoring and calibrating level indication instruments; or liquid entraining studies. For some complicated applications, several stationary monitoring points on a column are needed for observing the dynamic changes of different locations simultaneously. ❐

Typical stationary monitoring position



square of the vapor flowrate (range A-B). As the vapor rate continues to increase, eventually a point is reached when the vapor begins to interfere with the downward liquid flow, holding up liquid in the packing. The increase of the pressure drop is proportional to the vapor rate raised to a power greater than 2 (range B-C).

At this point, the pressure drop starts to increase rapidly because the accumulation of liquid in the packing reduces the void area available for the vapor flow. This area is called the "loading region". As the liquid accumulation increases, a condition is reached where the liquid phase becomes continuous. The slope of the pressure-drop curve increases further where even small increases in vapor flow significantly increase the pressure drop. Point C is usually referred as the flood point.

The problem with this traditional approach is the difficulty in differentiating between the transition points of the loading or flooding in the pressure-drop curve. Some suggestions for the definition of when a packed column becomes fully "flooded" are [*1*]:

- The slope of the pressure drop curve goes to infinity
- The gas velocity is so great that efficiency goes to zero
- Pressure drop reaches 2 in.H_2O per foot of packing
- Pressure drop rapidly increases in a region, with simultaneous loss of mass-transfer efficiency

Even for laboratory columns with excellent controls, it is still difficult to consistently predict the flooding point based on pressure drop alone. Fortunately, as with trayed columns, gamma scanning can help to diagnose the stages of flooding, and the apparent point where flooding begins in packed columns.

Gamma scanning is able to detect areas of, and to quantify the amount of, liquid accumulation in packed columns. The breaking point of accumulation that constitutes "flooding," however, depends on the level of performance for which you are striving.

There are two forms of liquid holdup in packed columns. One is referred to as static holdup. Static holdup is the amount of liquid that is held onto the packing after it has been wetted, then drained – the film of liquid or droplets of liquid that adhere to the packing. This amount jointly depends upon the physical properties of the liquid and the type and material of the packing.

The second aspect is the operating or dynamic holdup. Dynamic holdup is the amount of liquid held in the packing by the interaction of the vapor and liquid flows. Dynamic holdup must be measured experimentally. To measure this amount, instantaneously stop the liquid and vapor flows, then collect and measure the volume of liquid that drains from the packing. The total liquid holdup in packing is the sum of these two forms of holdup.

Alternatively, in a plant column, the best way to measure the liquid holdup on a macro scale is to do a baseline gamma scan of the column at "safe" operating rates — rates known to be well below any operating limit of the column. A scan at these conditions is a measure for future reference of the "normal" liquid loading of the packing.

To study flooding with scans, you should examine how the total liquid holdup changes — specifically, how much it changes and where the accumulation begins. Since the static holdup is constant, the operating or

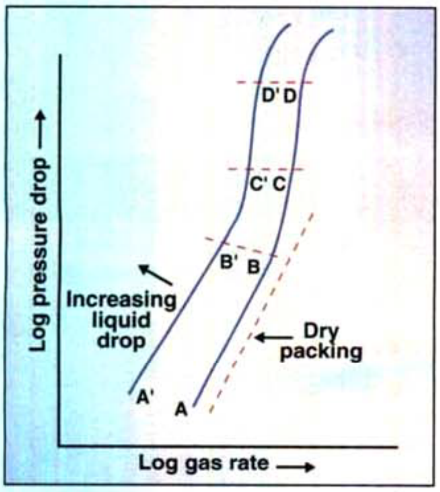


FIGURE 9. Typical pressure drop characteristics of packed columns [1]

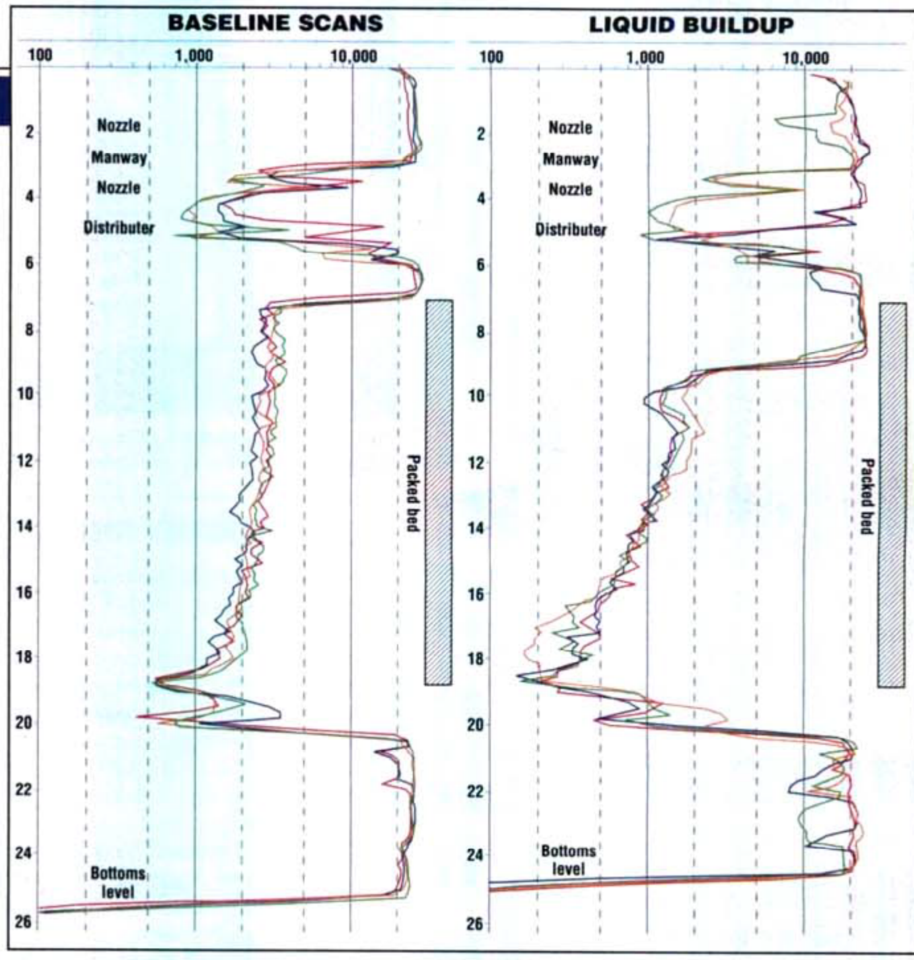


FIGURE 10. Left plot: baseline scans show the density gradient through the packed bed with accumulation of liquid at bottom of the bed. Right plot: mass of liquid built up in the bottom of the bed is probably due to crushed packing

dynamic holdup changes in proportion to changes in liquid and vapor rates. The void fractions in a packing bed may change across the bed due to fouling or damage, and vapor-liquid loads may be different along the bed for different operation conditions. The peak loading could occur anywhere in a packed bed, or a liquid distributor could initiate the flooding. Any theoretical correlation or traditional measurement, such as pressure drop, will not help very much in identifying the flooding point. Gamma scans simplify the flooding identification to a measurement of liquid holdup in columns.

Liquid accumulation vs. IFP

The left-hand plot in Figure 10 is a baseline scan of a packed column following a turnaround. The column was operating in a regime where it was meeting all its expectations for product separation, throughput and pressure drop. The most noticeable feature in Figure 10 is the density gradient through the packing, with the process density increasing towards the bottom of the packing. The increasing density indicates that there is more accumulation of liquid in the bottom than the top of the packing bed. This raises the possibility that the bottom section of the packed bed could be the IFP of the column.

The second scan (right-hand plot in Figure 10) is a scan of the same column (actually done prior to the turnaround and baseline scan) when it was known to be having problems. The density gradient through the packing is even more pronounced. There is also very bad liquid maldistribution in the bottom of the packing. (The scan lines are spread widely apart.) It is obvious, even at first look, that the bottom-packing region is flooding. Comparison to the baseline as a reference confirms that the incipient flooding point was indeed at the bottom of the bed. As one can also see from the scan plot, the packing bed height was less than it should have been, indicating crushed or damaged packing in the bottom as the cause of the flooding.

An interesting phenomenon for random packing and most corrugated-sheet packing is that the separation efficiency of an "initial flooding" bed could be better than a "normal" bed, because of high liquid holdup and intimate vapor-liquid contact in the "frothing" regime [4]. Figure 11, Points B-F shows a "hump" or low HETP (and, thus, high efficiency) on the plot of HETP vs. flowrates before the bed is fully flooded. But at the high-efficiency state it is difficult to keep the column operation stable, and the column could go out of control as a result of any slight process turbulence. For this reason, it is always recommended to avoid designing a packed column close to the initial flooding point. In operation, we would then not be overly concerned with some liquid accumulation or holdup, as long as the column could be kept stable and under control.

Let us look at a case where the liquid accumulation started at the top of a packed bed. The scan in Figure 12 shows an excess accumulation of liquid near the top of the packing (the gamma counts of scanlines are lower at the top of the bed than they are further down). The scan also shows poor liquid distribution at the top of the bed. The liquid distribution actually seems to improve in the middle of the bed.

Nevertheless, in this case, the column was not performing satisfactorily. Therefore the performance loss seemed to be due to the flooding occurring in the top of the bed. Since this column had operated at these conditions satisfactorily in the past, this was a "new" condition – not a design or packing capacity restraint. Under this basis the most likely reason for the excess liquid accumulation would be

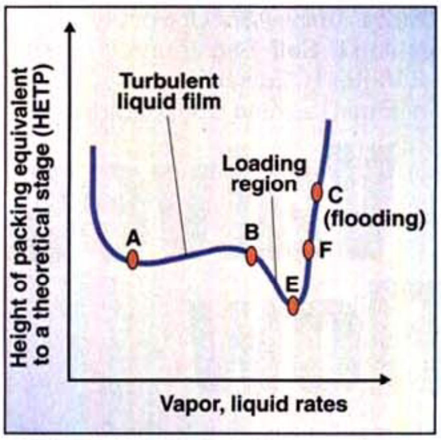


FIGURE 11. Typical efficiency characteristics for random packing and most structured packing [1]

fouling or damaged packing. Indeed, an inspection on the next turnaround found fouling on the liquid distributor and in the top layers of packing.

Localized restrictions

The scan example in Figure 13 shows a packed column where the measured liquid level on the top reflux distributor indicates that liquid in the distributor trough is full and overflowing. Note the excess accumulation of liquid (area of higher density) in the top of the packing. The flooding subsides and the liquid distribution improves proceeding further down the bed. Presumably the reflux flow alone was not enough to flood the packing. Excess liquid that unevenly pours to some spots could overload some areas of the packing bed and cause premature flooding. A full and overflowing distributor could also generate an excessive amount of condensed liquid and induce localized flooding in the bed.

Another problem due to condensing an excess of vapor involves a unique situation for petroleum refineries, particularly in a packing bed used for heat transfer (pump-around section). Through a pump-around bed, the liquid-vapor ratio is constantly and significantly changing during the heat transfer. Recalling that the dynamic liquid holdup is a function of the void fraction and the liquid and vapor rates, we can reasonably expect that there could be some combination of liquid and vapor where excess liquid accumulates in the packing. As with the other cases described in this article, there is no reliable correlation to estimate or predict this form of flooding. The best approach is to use gamma scans to detect when and where the excess accumulation occurs. ■

Edited by Rebekkah Marshall

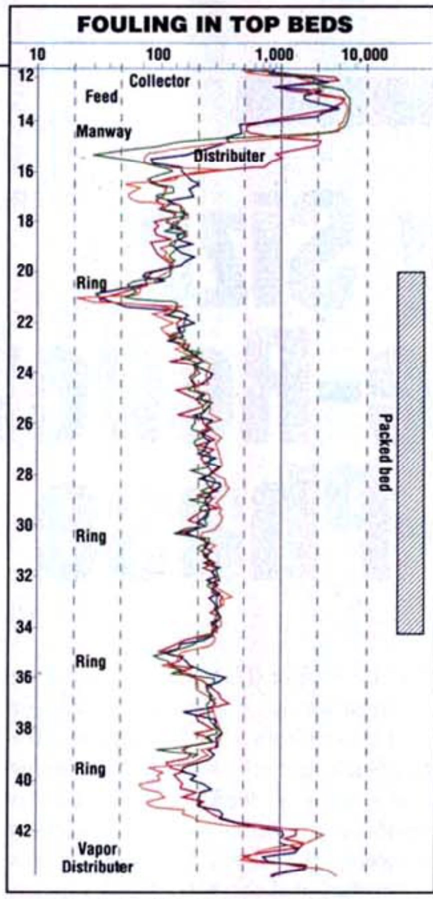


FIGURE 12. Shown here are the gamma-scan results for a packed column with an overflowing liquid distributor and liquid accumulation at the top of the bed

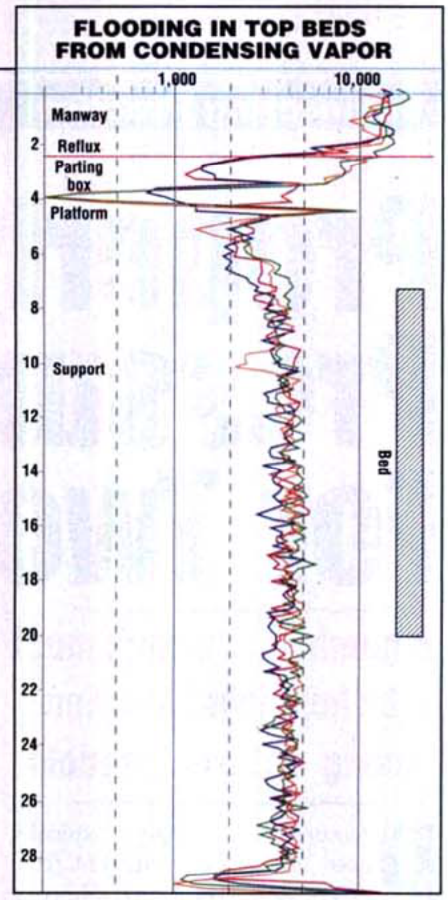


FIGURE 13. This packed column shows excess liquid accumulated in the top of the bed. Although the reflux-distributor parting box is overflowing, liquid flow alone is not enough to flood packing

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